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Durability of hand-sewn valves in the right ventricular outlet

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Objective: The objective was to compare the medium- and long-term outcomes for pericardial monocusp valves, polytetrafluoroethylene (Gore-Tex, WL Gore and Associates Inc, Flagstaff, Ariz) 0.1-mm monocusp valves, and bileaflet 0.l-mm polytetrafluoroethylene valves and their efficiency in the right ventricular outlet.

Methods: We reviewed all hand-sewn right ventricular outlet valves created by the author (Graham R. Nunn) in the setting of repaired tetralogy of Fallot or equivalent right ventricular outlet pathology when the native pulmonary valve could not be preserved. The valves were assessed by serial transthoracic echocardiography and more recently by magnetic resonance imaging angiography for late valve function. The bileaflet polytetrafluoroethylene valves were constructed in a standardized fashion from a semicircle of 0.1-mm polytetrafluoroethylene (the radius of which equaled the length of the outflow tract incision) that gave a lengthened free edge to the leaflets, central fixation of the free edge posteriorly just proximal to the branch pulmonary arteries, and generous augmentation of the outflow tract with polytetrafluoroethylene patch-plasty. The bileaflet configuration shortens the closing time against the posterior wall, and the leaflets are forced to maintain their configuration without prolapse into the right ventricular outlet. The valve can be generously oversized in young children to try to avoid the need for replacement.

Results: A total of 54 patients met the selection criteria—22 patients received fresh autologous pericardial monocusps, 7 patients received polytetrafluoroethylene (0.1-mm) monocusps, and 25 patients received bileaflet polytetrafluoroethylene (0.1-mm) outlet valves. The pericardial valves have the longest follow-up, and all valves developed free pulmonary incompetence. Polytetrafluoroethylene monocusps had reliable competence early after surgery but progressed to pulmonary incompetence. The bileaflet polytetrafluoroethylene (0.1-mm) valves have remained competent with regurgitant fractions of only 5% to 30% (magnetic resonance imaging angiography), and this has remained stable with time. The maximum follow-up for these valves is 5 years. No stenosis or peripheral emboli have been recognized, and no valves have been replaced to date.

Conclusion: Hand-sewn bileaflet polytetrafluoroethylene valves in the right ventricular outlet can reliably provide competence and maintain function in the medium term. Their shape and size allow placement in young children with a reasonable expectation that they will remain competent with growth of the native annulus and not require replacement. Their durability is superior to the pericardial and polytetrafluoroethylene monocusp valves in this series.

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Relief of right ventricular (RV) outlet obstruction in congenital cardiac surgery is an important principle, but it brings with it the dilemma of competence of the RV outlet. Valves and valved conduits provide excellent competence and short and medium-term relief of obstruction. However, biological tissues have shown a distinct degenerative capacity in the RV outlet with a significant incidence of obstruction in time.

Monocusps have been seen as a simple method of providing competence in the RV outlet that requires transannular patching in the perioperative period.[1-4] This may

Abbreviations and Acronyms
MRI = magnetic resonance imaging
PTFE = polytetrafluoroethylene
RV = right ventricular

translate into a safer perioperative period and more rapid recovery. Others have demonstrated this and confirmed the preservation of some or all valve competence with time when the valve is constructed of a 0.1-mm polytetrafluoroethylene (PTFE) (Gore-Tex, WL Gore and Associates Inc, Flagstaff, Ariz) sheet.[1,5,6] Others have not found useful valve function late after PTFE monocusp valve construction in the RV outlet.[3,7] Various modifications of valves constructed using PTFE membrane have been described.[1,8-10]

Materials and Methods

All patients in whom a hand-sewn valve was created in the RV outlet for pulmonary incompetence in a single surgeon's (GRN) experience have been reviewed. No institutional approval was required for this procedure that has long been practiced and documented at our own institution and reported widely in the literature (The children's hospital at Westmead). The series is consecutive with pericardial valves inserted from February of 1992 to October of 1998, PTFE monocusp valves inserted from April of 1998 to November of 2002, and bicuspid valves inserted from June of 2003 to the present. One pericardial monocusp valve overlaps the PTFE monocusp series.

Valves inserted were hand-sewn, untreated, autologous pericardial monocusps, hand-sewn 0.1-mm PTFE monocusps, and hand-sewn bicuspid 0.1-mm PTFE valves. The bicuspid valves were an evolution of the PTFE monocusps. The addition of a posterior fixation suture allowed the valve shape to be changed to increase its ability to better coapt to the posterior outflow tract and to have a greater opening orifice size without compromising its speed of opening and closing within the cardiac cycle. These are the most recent valves in the series. The indication for surgery, need for additional follow-up procedures in the RV outlet, and assessment of the competence of the valve by echocardiography in all patients and more recently by magnetic resonance imaging (MRI) techniques in some patients were evaluated. All patients received PTFE patch augmentations in the RV outflow tract with only the width of the patch and therefore the degree of augmentation varying. No patients received anticoagulation or antiplatelet agents in the postoperative period. Patients received outflow tract valves at the time of surgery when the native valve was small and destroyed or rendered incompetent by intended extensive outflow augmentation. This decision was made intraoperatively and was consistently applied throughout the study. Those patients with pulmonary atresia and ventricular septal defect with continuity between the pulmonary artery and the right ventricle that could be repaired as in tetralogy of Fallot were included. Those patients requiring conduits to bridge pulmonary artery deficiency were not included. Late valve insertion for dilating right ventricles was performed after canvassing all options with patients and parents, and informed consent was obtained preoperatively in all 13 cases.

Surgical technique remained constant: full bypass support, bicaval venous cannulation, moderate hypothermia, cold blood cardioplegic arrest of the heart, and closure of all septal defects before RV outlet valve construction. Valve construction was included in the ischemic period of the heart for the smaller children and was constructed with the heart perfused and beating for larger children. The RV outlet area was exposed with the aid of retraction sutures. Monocusps were constructed as described by others[1] using fresh autologous pericardium or 0.1-mm PTFE. Bicuspid valves were constructed using 0.1-mm PTFE cut as a sector of a circle with the radius of the circle equaling the length from the distal posterior wall of the pulmonary artery where the leaflet is attached to the proximal end of the incision in the RV outlet. This shape gives the maximum length to the free edge. This sector is folded, sutured distally first with a pledgeted nonabsorbable suture, and then sutured to the myocardium at the proximal end of the ventriculotomy before both sides are attached to the edges of the ventriculotomy. This sequence allows the patch to be shortened, if too large, proximally, and then the 2 sides are adjusted for width to give a higher open valve in the patient in whom more augmentation of the outlet is required. The edges of the PTFE are sewn from the proximal to distal ventriculotomy and arteriotomy edges so the final position of the free edges of the valve can be adjusted as the final step in valve creation if necessary. The time taken to construct each valve was similar; the valve (pericardial or PTFE) was sewn into the RV incision with a separate suture line to that attaching the RV outlet patch in all cases. The bicuspid PTFE valve was not more difficult to construct and could be fashioned readily for all (native plus PTFE augmentation) outflow tract sizes (Figures 1–6).

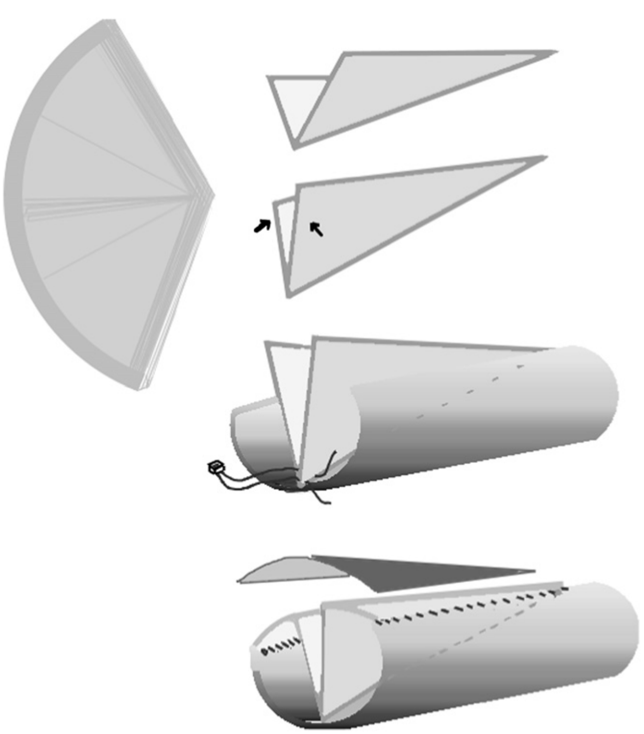

Figure 1. Steps in fashioning the valve into the RV outlet.

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Figure 2. Finished bicuspid PTFE (Gore-Tex, WL Gore and Associates Inc, Flagstaff, Ariz) valve with augmented RV outlet.

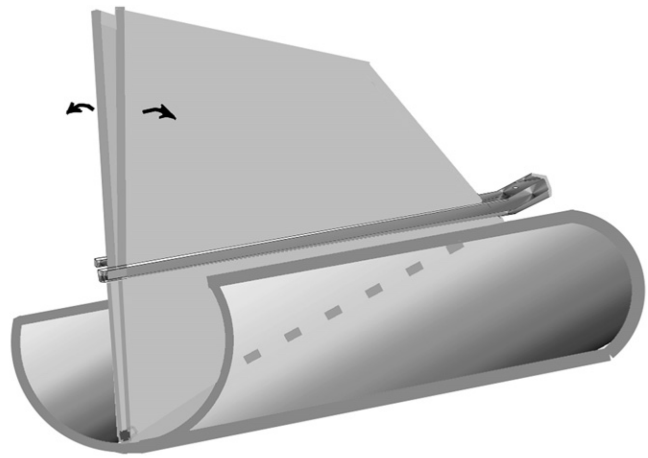

Figure 4. A vascular clamp is an excellent temporary adjunct to help accurately fold the 2 leaflets and then adjust the valve size depending on the need for a large or small patch augmentation of the RV outlet.

Valves were assessed independently by cardiologists experienced in echocardiography in all cases at the time of routine follow-up visits, with grading of valve competence reported as minimal, mild, moderate, severe, or free of pulmonary regurgitation. MRI assessments (13) were performed and reported independently by the hospital's radiologists.

Results

Fifty-four patients have had valves placed in the RV outflow tract. Among these, 50 patients have undergone 1 operation, with 18 patients receiving an autologous unfixed monocusp at the time of their definitive repair.

Six patients received a 0.1-mm PTFE monocusp, 25 patients received a bicuspid 0.1-mm PTFE RV outlet valve substitute, and 1 patient received an autologous bicuspid pericardial valve substitute.

Five patients have undergone more than 1 operation on the RV outlet. Four of these patients had first received a pericardial monocusp valve, which were replaced in 2 patients with a homograft (1 unstented porcine valve and 1 bicuspid PTFE valve).

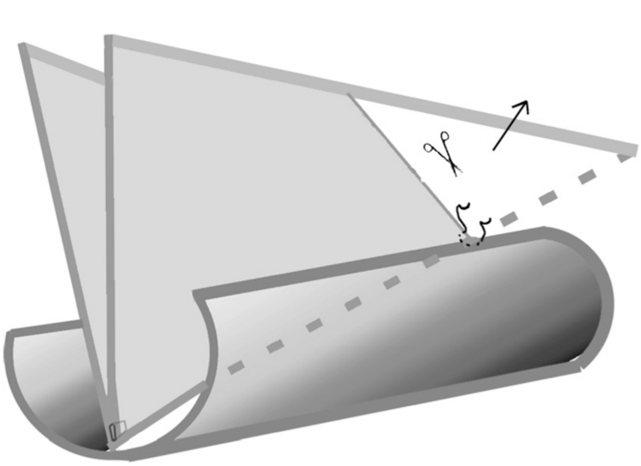

Figure 3. The folded leaflets can be trimmed proximally in situ and then sutured after fixing the distal free edge so the valve length is accurate.

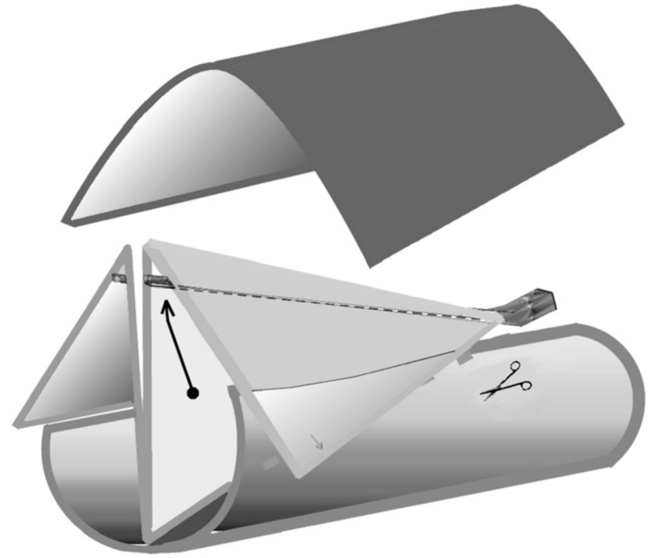

Figure 5. Large patch augmentation requires longer leaflets to the valve, and this can be easily achieved by the angulation of the vascular clamp as the leaflets are folded.

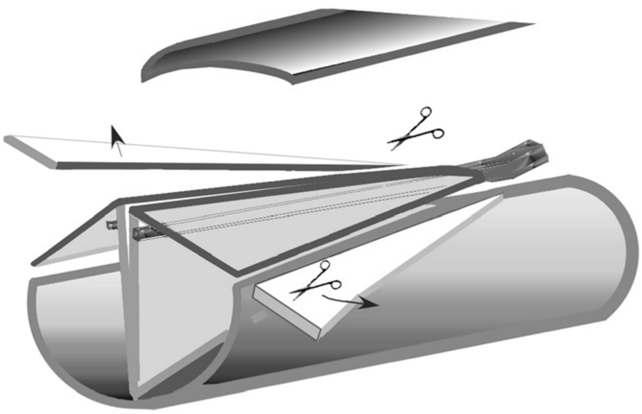

Figure 6. Smaller patch augmentation requires smaller leaflets, and the excess is easily trimmed off accurately before removing the vascular clamp.

One patient who originally received a PTFE monocusp underwent replacement with a bicuspid PTFE valve. Therefore, there are 27 bicuspid valves available for follow-up; 1 pericardial bicuspid valve and 21 pericardial monocusps have follow-up, with 17 remaining in situ at this time. Seven PTFE monocusps have follow-up, with 6 remaining in situ at the present.

The RV outlet valve was placed in 39 patients with tetralogy of Fallot, 1 patient with absent pulmonary valve tetralogy, 4 patients with pulmonary atresia and ventricular septal defect, 6 patients with pulmonary atresia and intact ventricular septum, 3 patients with double outlet right ventricle and severe pulmonary stenosis, and 1 patient with critical pulmonary stenosis (Table 1).

A valve was first placed in the RV outlet at a median age of 1.18 years. Pericardial monocusps were placed at age 1.54 ± 1.9 years (median 0.89 years); PTFE monocusp valves were placed at age 0.83 ± 0.43 years (median 0.94 years); and PTFE bicuspid valves were placed at age 0.98 ± 0.55 years (median 1.1 years). Although these ages vary, the groups were not statistically different because of the small sample sizes.

Thirteen of the patients had their first valve inserted in the RV outlet some time after their lesion had been "repaired" (Table 2). Valves were inserted in these 13 patients because the right ventricle was dilating in 8 patients, there was an increasing gradient in 4 patients, and there was an increasing gradient and a dilating right ventricle in 1 patient.

For the group with pulmonary atresia and intact ventricular septum, including the patient with critical pulmonary stenosis, 2 patients had increasing gradients and 3 patients showed progressive dilatation of the right ventricle. There were 7 patients in the tetralogy of Fallot group (including the patient with absent pulmonary valve): 4 patients with dilating right ventricle, 1 patient with dilating right ventricle and increasing gradient, and 2 patient with increasing gradients. The 1 patient with pulmonary atresia with ventricular septal defect repair received a valve for a dilating right ventricle.

Follow-up

Follow-up of the 54 cases shows that 1 child with pulmonary atresia and intact septum who received a pericardial monocusp at 2 days of age died perioperatively. One child with well-repaired tetralogy of Fallot died 3 years after surgery; the child developed viral myocarditis 6 months before death.

TABLE 1. Cardiac lesion, valve inserted and age at surgery for repair

Lesion	No.	Valve type	Age at operation (y)
Tetralogy of Fallot	39	Pericardial monocusp = 14; PTFE (Gore-Tex, WL Gore and Associates Inc, Flagstaff, Ariz) monocusp = 6; bileaflet PTFE (Gore-Tex) = 19	1.05 ± 0.5 y Median 0.95 y
Tetralogy of Fallot Absent pulmonary valve	1	Pericardial monocusp = 1	0.24 y
Pulmonary atresia with Ventricular septal defect	4	Pericardial monocusp = 2; PTFE monocusp = 1; bileaflet PTFE = 1	2.2 ± 1.25 y Median 1.8 y
Pulmonary atresia with intact ventricular septum	6	Pericardial monocusp = 3; bileaflet PTFE = 3	1.5 ± 3.2 y Median 0.1 y
Double outlet right ventricle with pulmonary stenosis	3	Pericardial monocusp = 2; bileaflet PTFE = 1	1.5 ± 0.4 y Median 1.2 y
Critical pulmonary stenosis	1	Bileaflet PTFE = 1	2 d
Total	54		

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TABLE 2. Repaired lesions requiring late insertion of right ventricular outlet valve

Patient lesion	Age first "repaired"	Interval to RVOT valve insertion
Pulmonary atresia intact ventricular septum	2 d	7.9 y
Pulmonary atresia intact ventricular septum	3 d	1.3 y
Pulmonary atresia intact ventricular septum	13 d	14.2 y
Pulmonary atresia intact ventricular septum	50 d	15.6 y
Pulmonary atresia with ventricular septal defect	1.1 y	13.9 y
Critical pulmonary stenosis	5 d	2.4 y
Tetralogy of Fallot with absent pulmonary valve	0.3 y	8.3 y
Tetralogy of Fallot	0.7 y	0.6 y
Tetralogy of Fallot	0.73 y	9.1 y
Tetralogy of Fallot	0.95 y	5.3 y
Tetralogy of Fallot	1 y	7.5 y
Tetralogy of Fallot	1.6 y	11.5 y
Tetralogy of Fallot	2.6 y	14.7 y

RVOT, Right ventricular outflow tract.

Echocardiographic surveillance in follow-up is shown in Table 3. Twenty-two pericardial monocusps were placed. One child died postoperatively, and 17 pericardial monocusps remain in place. Two patients have mild pulmonary incompetence (12%), 4 patients have moderate incompetence (25%), 9 patients have free incompetence (56.25%), and 1 patient has mild pulmonary stenosis (18 mm gradient) (6.25%). The other 2 patients both have had serial echocardiography, but no cardiologist reports have been issued; thus, they are not reported. Four monocusps have been replaced, 2 with homografts, 1 with an unstented porcine valve, and 1 with a bicuspid PTFE valve.

Seven PTFE monocusps have been placed, 6 remained in situ and 1 was replaced by a bicuspid PTFE valve. Of those valves in place, 1 has mild pulmonary incompetence (16.7%), 3 have moderate incompetence (50%), and 2 have free pulmonary incompetence (33.3%). No significant outflow gradients exist by echocardiography in either the pericardial or PTFE monocusp groups in follow-up.

Twenty-seven bicuspid PTFE valves are available for follow-up. Twenty-five valves were inserted at the time of repair, 1 valve replaced a pericardial monocusp, and 1 valve replaced a PTFE monocusp.

Echocardiographic follow-up (Table 3) shows minimal to mild pulmonary incompetence in 25 patients (92.6%) and moderate pulmonary incompetence in 2 patients (7.4%). None have free pulmonary incompetence. Thirteen of the patients (48%) have mild outflow gradients estimated at 10 to 25 mm Hg by echocardiography. Serial assessment of valve competence after the early postoperative period has shown little change with time in reported valve competence. MRI has become available in the latter part of this series, and to date 13 patients have been investigated. General anesthesia was used for each study. These patients all have bicuspid PTFE valves in place.

The MRI calculated regurgitant fraction of the substitute PTFE bicuspid valve ranges from 4% to 29%, with an average regurgitant fraction of 14.7% ± 7.5% and a median regurgitant fraction of 11.5% (Figures 7 and 8; Table 4).

Thirteen patients have been investigated by both echocardiography and MRI. Relatively good correlation was observed between the 2 modalities, but the subjective nature of echocardiography was evident in its inability to distinguish minimal and mild incompetence. Both had similar MRI regurgitant fractions. Larger patient numbers may give more useful information about the relative accuracy of each assessment modality.

Discussion

Free-hand insertion of valves in the RV outlet does allow the valve to be readily tailored to the size and shape of the outlet, and this is an advantage The position of the free edge of the leaflet(s) is important with good approximation to the posterior pulmonary artery wall or distal RV outlet essential for competence.[8] Placing this intended point further distally in the main pulmonary artery increases the likelihood that the valve will be competent without prolapse

TABLE 3. Echocardiographic assessment of all valves inserted

RV outlet valve type	Average follow-up, y	Median follow-up, y	Percentage of group with moderate to severe pulmonary incompetence	Percentage of group with mild pulmonary incompetence
Pericardial monocusp valve	10.5 ± 2.9 y	9.4 y (5.3–15 y)	88%	12%
PTFE (Gore-Tex, WL Gore and Associates Inc, Flagstaff, Ariz) monocusp valve	6.7 ± 1.25 y	6 y (4.5–7.7 y)	83%	17%
PTFE (Gore-Tex) bicuspid valve	2.6 ± 1.1 y	2.7 y (0.7–4 y)	7%	93%
Pericardial bicuspid valve (1 case)	5.4 y	5.4 y	0%	100% (1 case)

RV, Right ventricular; *PTFE,* polytetrafluoroethylene.

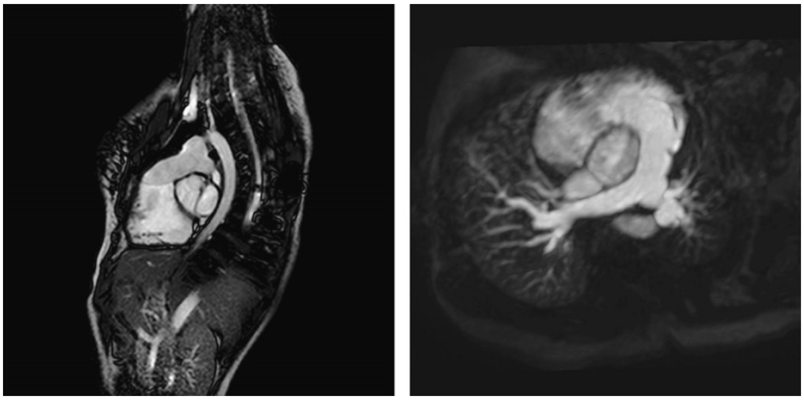

Figure 7. Magnetic resonance images showing competence of the bicuspid PTFE valve in the lateral view and no interference to flow in systole in the craniocaudal view. This valve has been inserted for dilatation the right ventricle after repair of pulmonary atresia and closure of ventricular septal defect 14 years previously.

and increases the leaflet area, thus reducing the wall stress in the leaflet and the likelihood that it will disrupt around its margins.

The addition of a fixation suture at the free edge of the leaflet posteriorly organizes leaflet motion between systole and diastole, forces the free edge to coapt without prolapse, and decreases the time it takes the 2 halves of the free edge to move from fully closed to fully open positions. It also allows a greater degree of overcorrection in size in the RV outlet because the valve can be crafted to fill any outlet, which can to a certain extent then accommodate growth. The hinge point in the leaflets changes as the 2 leaflets move from fully open to fully closed, and this may prevent buildup of fibrinous material at a hinge point that in the monocusp is fixed, as has been shown to be the point of fibrin accumulation.[1] Oversizing of the valve may superficially suggest that a capacitance chamber is created in the RV system that could reduce the volume delivered to the pulmonary arteries by each RV systole. This is, however, not the case. Each RV systole not only is ejected through the valve but also empties the volume of blood on the pulmonary arterial side of the leaflets as it forces them open. That volume is added to the pulmonary flow for that systole and returns from there to the pulmonary arterial side of the valve when it closes, thus preserving systolic volume delivered to the pulmonary arterial tree. This concept is similar to the volume of blood required to fill sinuses of Valsalva that also does not detract from systolic volumes delivered by ventricles. The bicuspid PTFE valves have been durable in the medium term, not lost competence in the follow-up period, and not resulted in significant obstruction in the RV outlet; however, follow-up is shorter for this group and longer term reassessment is necessary. They may represent an advance over the monocusp valves. No attempt has been made to compare these valves with modifications with existing leaflets that others have described but were not present in our series.

Conclusions

Hand-sewn valves constructed from 0.1-mm PTFE have not shown structural deterioration or calcification in this series. The valves fashioned as monocusps have lost their competence (88%) in almost all cases. The valves fashioned as bicuspid valves using the same 0.1-mm PTFE membrane have retained their competence (93%) in most cases, and there has not been a deterioration in their function in the period of follow-up (Table 3).

These bicuspid valves are readily fashioned in place and do not require complex measurements or extensive

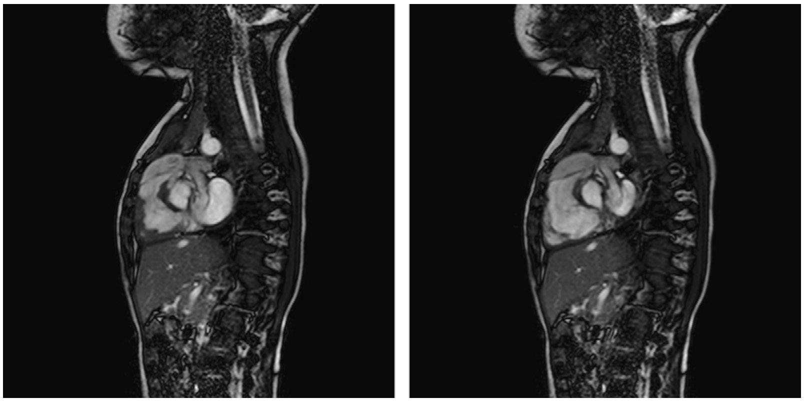

Figure 8. Magnetic resonance images in end systole and end diastole showing the bicuspid PTFE valve with little movement of the fold between the 2 halves of the leaflet throughout the cardiac cycle attesting to the stability of the valve shape. The distal placement of the valve free edge is apparent, just proximal to the branch pulmonary artery origins. This is an infant with repaired tetralogy of Fallot, and the oversizing of the valve is evident together with preserved ventricular function.

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TABLE 4. Comparison of echocardiographic and MRI assessment of RV outlet valve

Patient operation date	Years of follow-up	Echocardiography reports: RV outlet valve	MRI regurgitant fraction: RV outlet valve
September 2, 2004	2.7	Mild pulmonary incompetence	12.0%
September 8, 2004	2.6	Minimal pulmonary incompetence	16.0%
September 30, 2004	2.6	Mild pulmonary incompetence	23.0%
February 1, 2005	2.2	Mild pulmonary incompetence	11.5%
February 17, 2005	2.2	Mild plus pulmonary incompetence	18.0%
May 17, 2005	1.9	Mild pulmonary incompetence	18.0%
May 24, 2005	1.9	Moderate pulmonary incompetence	4.0%
October 15, 2005	1.5	Mild pulmonary incompetence	6.0%
October 20, 2005	1.5	Mild pulmonary incompetence	26.5%
December 1, 2005	1.4	No reports	10.0%
February 8, 2006	1.2	Minimal pulmonary incompetence	10.0%
February 15, 2006	1.2	Mild pulmonary incompetence	29.0%
August 23, 2006	0.7	Mild pulmonary incompetence	9.0%

RV, Right ventricular; *MRI,* magnetic resonance imaging.

intraoperative time to reliably create. The size of the valve is crafted to match the RV outlet regardless of the augmentation size.

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Discussion

Dr J. Brown *(Indianapolis, Ind)*. Dr Nunn and colleagues are to be commended on their development of another relatively simple technique to reconstruct the pulmonary valve with 0.1-mm PTFE membrane in patients who require a transannular patch. I have to admit that studying their illustrations and seeing the video clarified this technique immensely for me. Reading the abstract, I was a little confused. But you did a wonderful job in explaining how this valve works and how it's oriented in the RV outflow tract.

This technique lengthens the leading edge, or free edge, of the reconstructed pulmonary valve and has the potential advantage of enlarging the pulmonary valve to a greater diameter than can be accomplished with a monocusp valve and may shorten the leaflet closing time. The technique also orients the commissures of the new valve in a vertical manner as opposed to the monocusps, where the closure is in the horizontal manner.

The monocusp technique, using this material that my colleagues and I have used successfully at Indiana for more than 13 years and more than 200 patients, allows us to double the circumference of the native RV outflow tract, but it seems that this technique might allow you to enlarge it even further. I have several questions. Do you use aspirin postoperatively in your patients?

Dr Nunn. I haven't.

Dr Brown. Can you make this outflow tract reconstruction too large so that when you close the sternum it's compressed and this would deform this valve?

Dr Nunn. It's possible. But I think that the bileaflets, because they're held apart by that pledgeted suture, would still function to a degree with redundancy in their free edge, which is implied in your question, so I think it would still work, but I haven't had that experience yet.

Dr Brown. There obviously is some artwork involved with this technique to know how large to make the outflow tract patch itself. Do you have a rule of thumb that you use for how big you make it, or how big of an orifice through this outflow tract you want to have at the end of your repair?

Dr Nunn. I don't have a rule of thumb. For the tetralogies repaired primarily that needed this, I've used a 25-mm wide PTFE strip as the augmenting patch, but it can be larger.

Dr Brown. In at least 1 of your patients you had a 30% regurgitant fraction in this bileaflet or bicuspid valve. What was the nature, why did that valve leak, and why is there at least a small amount of leakage in all of these valves? Where does the leakage occur?

Dr Nunn. With the technique of MRI used here in a number of these patients, the normal mitral and aortic valves were assessed for their competence, and they regularly returned a 5% regurgitant fraction by this technique. So that a median regurgitant fraction of 11% isn't as bad as it may appear at first glance. That's the first thing.

I think the other is that I don't think I've made them all perfect, and I'm sure there is a learning curve in that. I'm convinced that I'm still learning. So whether the 30% valve was just a bad day, I don't know. When I started this, I thought that if they were going to fail they were going to fail as a monocusp does, and I'd left the patient with a reasonable chance of progressing to later growth and the need for another type of valve, as most repaired tetralogies with outflow tract patches have. So I felt comfortable that I could use this technique. I would have been happy at that point to accept a 30% regurgitant fraction. So to see them functioning sometimes at near-normal valve competence, as assessed by this technique of MRI, I was very happy with that.

Dr Brown. Our experience with a monocusp has been a little better in that at approximately 12 years postoperatively there is only moderate or greater regurgitation in approximately 50% at 12 years. It's promising that at least this technique may reduce that substantially, and for that I congratulate you for this new technique to further reduce the late development of pulmonary insufficiency in this important group of patients.

Dr G.-W. He *(Hong Kong, China)*. Congratulations for an elegant technique. My question is regarding the use of the monocusp valve. It was used in the early 1970s and 1980s. The reason that the monocusp was abandoned in the 1980s in most centers was because it was not functioning after 6 months for 2 reasons: First, some of the monocusps were absorbed, so it was not functioning. Second, some of the monocusps were calcified, so was not functioning because it was attached to the wall.

This is why I developed a new technique to create a monocusp-bearing pericardium patch. I reported this technique 2 days ago at the World Society for Congenital Heart Surgery meeting. I do believe that the use of a monocusp-bearing patch cannot be abandoned because in many of the patients who need RV outflow tract reconstruction, there are some remnants of the native valves. In my practice, in the last few years, I did 74 tetralogy repairs. Two thirds of them have at least 1 or 2 valves left. In such cases I do not think we really need to go too far to use your bicuspid pericardial patch, which has a lot of foreign body tissue in the low pressure pulmonary system that may need coagulation therapy. Do you really think your technique can be used for all patients with tetralogy or do we still need to use the monocusp?

Dr Nunn. Like you, I leave any useful valve remnants in the RV outflow tract and that's often 2 leaflets. So I share your desire to preserve pulmonary valve tissue.

I haven't seen any evidence of pulmonary emboli or thrombosis in the RV outlet or pulmonary arteries in these patients in follow-up. It may happen, but it hasn't yet.

I agree with you that pericardial monocusps do deteriorate. In this series, of the 22 pericardial monocusps, 5 were replaced, 1 with a bileaflet PTFE valve and 1 with homografts or freestyle porcine valves. My findings were that the monocusps were stuck to the free wall.

Dr He. I used the monocusp valve formed from the pericardium itself, fold up and sewn on the 2 sides. I think the results would be better than the traditional method that uses 1 patch sewn to another, because the calcification and the absorbable problem would be less.

Dr J. Jacobs *(St Petersburg, Fa)*. In 2005, Jim Quintessenza and I published our initial experience with 41 patients with PTFE bicuspid valves in older, larger patients. Our series is now up to 90 patients with a median age of 14.6 years, and our follow-up is about up to 6.4 years; 88 of these 90 valves are still functional and 2 of them had to be replaced. We initially used 0.6-mm PTFE, and now we've switched to 0.1-mm PTFE.

Would you use the valve that you've described in an older patient, a teenager, with late pulmonary insufficiency? If so, would you use 0.6-mm or 0.1-mm PTFE?

Dr Nunn. A number of these patients are in that age range. I still use the 0.1-mm PTFE. The 0.6-mm PTFE just adds momentum to the leaflets and stiffens the valve enough that it probably doesn't finish its opening or closing when the next cardiac cycle arrives. So that's one of the reasons I stayed with the 0.1. But having done that, it's a fragile membrane to work with, and so using a larger leaflet extending well into the pulmonary artery spreads the wall stress of the PTFE and allows tension to be taken off that posterior fixing suture.

Dr Jacobs. We were initially using the 0.6. After discussion with John Brown and having 1 failure when it got a little calcified, we switched to the 0.1, and we've been pretty happy with that by making a long leaflet just like you described.